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LEAF CURL AND PLUM POCKETS.

CONTRIBUTION TO THE KNOWLEDGE OF THE PRUNICOLOUS EXOASCEÆ OF THE UNITED STATES.

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LEAF CURL AND PLUM POCKETS.

CONTRIBUTION TO THE KNOWLEDGE OF THE PRUNICOLOUS EXOASCEÆ OF THE UNITED STATES.

The distortions of the leaves of the genus *Prunus* known popularly as leaf curl, and the hollow, spongy, abnormally enlarged fruits commonly called "plum pockets," or "plum bladders," are caused by certain fungi belonging to the family *Exoasceæ*. The *Exoasceæ* are composed largely of parasitic species which live upon many of the higher plants and are especially abundant upon the *Rosaceæ*. The family is characterized by the possession of fruit structures, termed asci, which are approximately cylindrical and stand, more or less crowded together, out upon the surface of the affected portions of their hosts.

Several attempts have been made to establish genera for what seemed to be natural divisions into which the members of the family grouped themselves. These genera were based principally upon the number of spores in the ascus. The known spore characters, however, in this family are so remarkably inconstant that nothing more than an unsatisfactory artificial classification has thus far been proposed upon that basis. Sadebeck* has recently proposed a more natural subdivision of the parasitic *Exoasceæ*. Those species in which the asci are not developed from a common subcuticular hymenium, but from the ends of intercellular hyphæ are made the ground for a new genus, *Magnusiella*. This genus is represented in the United States by the well known *M. potentillæ*† (Farl.) Sadeb., upon *Potentilla canadensis*. Those species

* Die parasitischen Exoasceen. Eine Monographie. Abgedruck. a. d. Jahrbuch d. Hamb. Wiss. Anstalten. x. 2. Hamburg, 1893.

† Exoascus deformans (Berk.) Fuckel var. potentillæ Farlow, Proceedings Amer. Acad. Arts and Sciences, XVIII, 1883, p. 84. Taphrina potentillæ Johanson, Oefvers. af. Kgl. Vet.-Akad Forh. 1885. Magnusiella potentillæ Sadeb. Abgedr. a. d. Jahrb. d. Hamb. Wiss. Anst. x. 2. 1893, p. 86.

in which the asci are developed from a common subcuticular hymenium are farther divided into two genera. Those with a perennial mycelium are placed in the Fuckelian genus *Exoascus*, while those lacking a perennial mycelium are placed in the Friesian genus *Taphrina*. *Taphrina* as thus emended contains species in which a new infection each year is brought about by spores. A common representative of the genus in this country is *T. coerulescens** (Mont. et Desm.) Tul. The species of *Exoascus* having a perennial mycelium, a new infection each year is secured by the mycelium which winters over in the tissues of the host, and by the spores.

The prunicolous species of *Exoasceæ* thus far known all belong to the genus *Exoascus*. These have for the present purpose the chief interest and farther discussion of the other two genera is not contemplated here.

Considerable material has accumulated during a period of observation extending over five years, which seemed to justify the preparation of the matter for publication. Especially does this seem to be the case since no comprehensive illustrated account of those species occurring on the stone fruits in the United States has as yet been attempted. The economic importance of the stone fruits suggested the appropriateness of presenting the contribution as a bulletin for the information of fruit growers, since a knowledge of the known characteristics and mode of perpetuation of the parasites will aid those interested in checking or preventing the injuries.

In making a critical examination of the material at hand it appeared that there were several well characterised undescribed species, a fact which was not anticipated at the outset. This is a sufficient explanation of the necessary use of much technical description in a portion of the paper.

No part of the plant is exempt from the attacks of these fungi except the roots. The first marked effects of their active presence in the tissues of the host is the stimulus to an increase in the number or size of the cells so that characteristic malformations of the diseased parts appear. In the leaves the increase in the num-

* Ascomyces coerulescens Mont. et Desm. Ann. d. Sci. Nat. Bot. ser. 3, x. p. 345. Taphrina coerulescens Tulasne, Ann. d. Sci. Nat. Bot. ser. 5, v. p. 127.

ber of the cells of the diseased portion causes that part of the leaf to arch upward or downward in a series of irregular folds, or a somewhat circular spot becomes strongly arched in one direction forming a deep, wide mouthed pocket. The twigs become enlarged in diameter and variously contorted, or an early development of the buds is stimulated producing what are commonly called "witches brooms." The fruit becomes transformed into a large spongy mass of tissue, which is hollow and devoid of the "stone" or "pit;" or only one side of the fruit is affected when irregular one sided swellings of similar tissue are developed. The floral envelopes in some species partake also of the hypertrophy, and in other cases only the superficial portion of the fruit is affected when the "stone" is normally developed. In the latter case sometimes a warted condition of the fruit appears. The young leaf buds of some species are transformed into a large spongy hollow mass, much resembling in texture the tissue of the "plum pockets." A number of these characteristic hypertrophied parts of various plant organs are illustrated in photographic reproductions in Plates I–X.

Mycelium. In all of the species at present known on the genus *Prunus*, with one exception,* the mycelium penetrates to some depth in the tissues, but it is always intercellular. It is quite characteristic and can usually be readily differentiated from the mycelium of other fungi when examined in situ. It is very irregular in its course and the size of its cells. These are cylindrical, oblong, clavate, or oval, and are joined in an irregular chain without order between the cells of the host. The mycelium may be quite abundant in some species so that when the other intercellular substances and portions of the cell walls of the host are dissolved out by the use of chloral hydrate, and differentiated by the use of some of the stains like eosin, it presents a very intricate network of threads. In other species or in parts of the plant not so seriously affected, or in parts where the mycelium is passing the winter, it is more scanty, frequently consisting of isolated, oval or irregularly oblong cells.

* Exoascus minor Sadebeck, Kritische Untersuch. ü. d. durch Taphrina-Arten hervorgebr. Baumkrankheiten. Abgedruck. a. d. Jahrb. d. Hamb. Wiss. Anst. VIII, 1891, p. 24.

Hymenium. From the interior of the tissues the mycelium grows to the surface and spreads, by branching, out over the epidermal cells just beneath the cuticle. The cells of the subcuticular layer soon become nearly isodiametric and are usually developed in such numbers that eventually they are closely crowded, when they become angular in outline. By a less profuse development they may appear as variously branched chains of oval cells. These subcuticular cells are very rich in protoplasm, much more so than the cells within the tissue. They make up what is called the hymenium. In figure 81 is shown a section of a portion of a deformed bud of *Prunus angustifolia* presenting the intercellular-mycelium and young hymenium of *Exoascus mirabilis* Atkinson. In fig. 83 is represented a surface view of a portion of the hymenium of the same species.

Each of the cells of the hymenium elongates perpendicularly to the surface, forming cylindrical or clavate cells which divide by a septum into two cells, the septum usually being near the base. The inner cell is the stalk cell while the outer cell is the ascus or fruiting cell. In each ascus there are developed a variable number of spores, usually four or eight. These are rounded, oval, or elliptical in form, and are colorless. At normal maturity a perforation usually occurs at the apex of the ascus and the spores are ejected with considerable force. The ascus becomes turgescent by endosmosis, this produces a pressure upon the walls and a rupture occurs at the weakest point, which is at the apex. De Bary* says that the ejection of the spores takes place in a manner exactly similar to that in various species of other Discomycetes which he examined. I have several times watched under the microscope the expulsion of the spores of some of the Discomycetes like *Dasyscypha virginea* (Batsch) Fuckel, *Propolis faginea* (Schrad.) Karst. *Trichopeziza capitata* (Peck) Sacc., and others. In the Pyrenomycetes I have watched the same phenomenon in the case of *Spherella pyri* Auersw. By mounting specimens which are not too old in fresh water and immediately noting the asci under the microscope they can be seen to become turges-

*Exoascus pruni und die Taschen oder Narren der Pflaumenbäume, Beiträge z. Morph. u. Phys. d. Pilze, Erst. Reihe. Abgedruck. a. d. Abhandl. d. Senkenb. Naturf. Gesellsch, Bd. V, pp. 183 and 184, Frankfurt, 1886.

cent and finally a rupture occurs at the apex and the spores are shot out suddenly. Usually the spores are all shot out together from a single ascus. De Bary* and Rathay† both placed freshly gathered specimens of *Exoascus* on a glass slip in a moist atmosphere and after several hours the glass was covered a distance of 1 cm. from the specimen with the spores, which formed a white ring around it.

When the fungus is mature the affected parts of the plant present a whitish or mealy aspect caused by the numbers of asci and free spores.

Each spore in water or in nutrient solutions is capable of producing, by a process of budding similar to that of the yeast plant, smaller and similar cells. In water the parent spore becomes by this process smaller also. This frequently takes place within the ascus when the spores are not expelled at maturity, so that after a while the ascus is quite well filled with these small conidia. DeBary,‡ Brefeld§ and Sadebeck|| record the results of attempts to grow the spores in artificial media. In no case was a mycelium observed to develop, but budding always took place where any growth appeared. By placing spores on the young leaf buds, or better on the leaves of seedlings, Sadebeck¶ succeeded in observing the entrance of a mycelium in the leaves of *Alnus*. The species experimented with was *Exoascus tosquinetii* (Westend) Sadeb. The mycelium was observed to enter through the stomata into the tissues.

We can now enter into a more detailed discussion of the hyper-

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* Ibid.

† Ueber die Hexenbesen der Kirschbäume, und Exoascus wiesneri n. sp Sitzungsb. d. Math.-Naturw. Classe d. k. Akad. d. Wiss. Bd. LXXXIII, Abth. I, p. 280, Wien, 1881.

‡ Exoascus pruni etc. Beiträge z. Morph. u. Phys. d. Pilze, Erst. Reihe, Abgd. a. d. Senkenb. Naturf. Ges. Bd. V. pp. 185, 186; 1886.

§ Unters. a. d. Gesammtgeb. d. Mykol. Heft IX, pp. 142, 144, Münster, 1891.

|| Die parasitischen Exoasceen. Abgdruck. a. d. Jahrb. d. Hamb. Wiss. Anst. X, 2 p. 13; 1893.

¶ Unters. ü. d. Pilzgattung Exoascus und die durch dieselbe um Hamburg hervorgerufen Baumkrankheiten. Abgedruck. a. d. Jahrb. d. Wiss. Anst. p. 102; 1883. Hamburg.

Die parasitischen Exoasceen. Ibid. X, 2, p. 13; 1893.

trophied organs of the various species of *Prunus*, and the morphology and structure of the infecting species of *Exoasceæ*.

PRUNUS PERSICA (L). Peach.

Exoascus deformans (Berk.) Fuckel.

The leaves and twigs are the only portions of the peach tree which are at present known to be affected with the fungus. The leaves are more commonly the place for the injury to be shown, and the twigs are but rarely attacked seriously or so as to attract attention. During June, 1894, I observed a tree on the Cornell University Campus having the leaf "curl" and a few of the ends of certain twigs were abnormally enlarged, though but slightly. One of these is reproduced from a photograph in Plate I, Fig. 1. The petioles of the leaf are also hypertrophied and profusely corrugated. From the petioles the hypertrophy can be seen to extend part way on the stem. Scribner* notes quite a serious injury to young shoots of nursery trees received from New York and transplanted at Knoxville, Tenn. The shoots for several inches below the leaf bud were considerably enlarged and presented a very much roughened or corrugated surface.

The disease in the leaves produces the distortions which are commonly spoken of as "leaf curl." With the increase in the number and size of the cells of the affected part the leaf is thrown into a series of irregular folds frequently transversely to the long axis of the leaf. Sometimes the arching of the leaf takes place more strongly on one side than on the other when a strong convexity appears on that side. When a large portion of the leaf is thus affected it frequently bulges out on one side along the middle and the edges of the leaf are drawn toward each other, the leaf appearing as if strongly inflated. In the affected portions of the leaf the green color pales and the parts are more or less brightly colored with reddish or yellowish tints. The leaf tissue at these parts is also thickened and assumes a "cartilaginous" consistence. The parenchyma cells are frequently very much elongated and curved or sinuous in form. The mycelium is perennial in the leaf buds, that is, it passes the late summer, autumn and winter months in the tissue of the leaf buds and in

* Fungus diseases of the grape and other plants, p. 126. 1890.

the following spring grows out with the developing leaf, multiplying more abundantly in certain portions than in others at times. This accounts for the fact that the whole area of the leaf is not at all times affected.

The persistence of the mycelium during the autumn and winter seasons in the leaf buds is probably the chief cause of the spread of the disease. When buds are taken for "budding" young seedlings in the nursery, if they are taken from an affected tree the disease is quite sure to be transmitted to every young tree which is started from a bud which contains the perennial mycelium. Since all of the affected leaves fall off from diseased trees at quite an early period, and at the time of budding the seedlings in August there is probably no sign of the curl in any of the leaves, it would be impossible to discriminate between the diseased and healthy trees, or the affected and free branches. An early selection of healthy trees for budding purposes would prevent the transmission of the disease through nursery stock.

Some experiments have been made in various places by spraying the trees with the Bordeaux mixture for the prevention of the leaf curl of peach trees. Some of the experimenters regard it as certain that the disease can to some extent be checked by this method. It is quite likely that, in some cases at least, another disease is confused with the leaf curl, and this fact might account in those instances for the results claimed. More definite experiments with an accurate determination of the diseases present should be made before too much can be claimed for the efficacy of the application of sprays for the prevention of this trouble.

The asci are developed on both surfaces of the leaf. Before the young asci pierce through the cuticle in their development they frequently raise the cuticle somewhat when it appears on drying as a thin whitish glistening membrane. The asci are nearly cylindrical, sometimes slightly clavate, and rounded or truncate at the free ends. They measure 25*–40 long by 8–11 in diameter, the larger number possessing intermediate measurements and being 30–35 by 9–10. The stalk cells are 6–8 high and 6–9 or 10 in diameter. They frequently taper considerably

* Measurements where not otherwise stated are given in terms of the micromillimeter.

toward the base and often are quite sharp pointed. Occasionally where they are not much crowded the stalk cell is considerably broader, attaining a diameter quite equal to that of the ascus at its distal end, while it will be broader than the lower end of the ascus. The pointed ends of the stalk cells frequently intrude somewhat between the cells of the epidermis.

The number of spores in an ascus is usually eight or approximately that number. They are rounded or oval and measure 3–4 in diameter. Sometimes the number is quite constantly four in a large number of asci and then the diameter is considerably greater, reaching 5 or 6. Asci with only four spores were found by me quite frequently on specimens of peach leaves distributed in Seymour and Earle's Economic Fungi, Fasc. I No. 14, and collected in Temple, N. H., June 18, 1888. A few of these are illustrated in fig. 21. Sadebeck* records the same variation in the case of *Exoascus epiphyllus*, *E. farlowii*, *Taphrina ulmi*, *T. bullata*, and others. Brefeld† suggested that according to the custom of some authors in using the number of spores as a basis for the separation of genera that the four spored *Exoasceæ* should be separated from the eight spored ones. Eight spored asci, however, present very great variations in a number of Ascomycetes so that in asci from the same perithecium there may be four, six or eight spored asci. Several species of *Teichospora* may be cited as examples of this.

PRUNUS AVIUM L. English Cherry.

Exoacus cerasi (Fuckel) Sadeb.

This species, *Exoacus cerasi* (Fuckel) Sadeb. has been found on "escaped cherry trees" at Germantown, Pa., by Prof. Thomas Meehan. It was distributed in Ellis, N.A.F. No. 2286, as *Exoascus wiesneri* Rathay.

This fungus forms the well known "witches brooms" of *Prunus avium* and *P. cerasus* in Europe. The mycelium is perennial in the affected twigs, the fructification only showing upon the leaves. In response to an inquiry Professor Meehan writes that

* Die parasitischen Exoasceen. Abgedruck. a. d. Jahrb. d. Hamburg. Wiss. Anst. X, 2, pp. 8–9. 1893.

† Unters. a. d. Gesammt. d. Mykol. IX, p. 144, Münster, 1891.

the twigs are not deformed, but instead of forming spurs, or flower buds, as in ordinary branches, twigs are produced and this gives the broomy appearance. The presence of the mycelium thus stimulates an early and profuse development of twigs so close together that it roughly stimulates a broom. The asci in the specimens which I have seen occur on the under side of the leaf, though Robinson* says they occur on both surfaces. The leaf is deformed, presenting a series of folds and wrinkles, and the fructification shows as a dense whitish layer on the surface. The fungus was first described by Fuckel† as *Exoascus deformans* b, *cerasi*. Rathay‡ made a critical study of the perennial mycelium and the peculiarities of the infected branches, and named the fungus *Exoascus wiesneri*. It has been considered by many as only a form of *Exoascus deformans* (Berk.) Fuckel, and Robinson|| refers it to that species though he notes that the asci are much more slender than those of the typical form on the peach, the stalk cells proportionately much longer and they do not taper below as in that species. Sadebeck§ regards it as a distinct species but accepts the varietal name given it by Fuckel and writes it *Exoascus cerasi* (Fuckel) Sadeb. It appears to me that it is well distinct from the species on the peach.

The asci are cylindrical and rounded or truncate at the free ends. According to Sadebeck¶ in the European specimens they measure 35–50 long by 7–10 in diameter. He remarks that there is great variability in the size of the asci. In the specimens from Germantown, Pa., which I have seen the asci measure 25–33, long by 6–9 in diameter. The stalk cells 10–17 high by 5–7 in diameter. The more common length for the asci is about 30. The spores are approximately eight in an ascus, and are round or oval. The details of the asci and spores are shown in fig. 25.

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*Notes on the genus Taphrina. Ann. Bot. I, p. 169, 1887–8.

†Symb. Mycol. p. 252, 1869.

‡Ueber die Hexenbesen der Kirschbäume und über Exoascus wiesneri, n. sp. Sitzungsb. d. Math. Naturw. Classe d. k. Akad. d. Wiss. Bd LXXXIII, Abth. I, p. 267, Wien, 1881.

||Notes on the genus Taphrina. Ann. Bot. I, p. 168–169, 1887–8.

§Kritische Unters. über die durch Taphrina-Arten hervorgebrachten Baumkrankheiten. Abgedruck. a. d. Jahrb. Hamb. Wiss Anst. VIII, p. 26, 1891.

¶Die parasitischen Exoasceen. Ibid, x, 2, p. 49, 1893.

PRUNUS PENNSYLVANICA L. Wild Red Cherry.

Exoascus insititiæ Sadeb.

I have referred to this species, specimens collected by Seymour at Temple, N. H., June 16, 1888, on the leaves of *Prunus pennsylvanica* L. It was distributed as *Taphrina deformans* (Berk.) Tul., in Seymour and Earle's Economic Fungi, No. 15. The specimen in the collection to which I have had access shows several small twigs curved to one side growing from the end of a larger twig. The specimen has very much the appearance of a small "witches broom." The young twigs are pale and slender, and the leaves are not much deformed, the upper surface being somewhat folded, while a large portion of the under surface is covered with the asci which give them a greyish white appearance. The mycelium is present in the inner tissue of the leaf but is not nearly so abundant as in the peach.

The asci are quite regularly smaller than those of *E. deformans* on the peach. Through the kindness of Mr. J. B. Ellis I have had the opportunity of seeing a specimen of this species on *P. domestica* from Sweden, and the asci are very much nearer those on that specimen than on the peach. In the measurements given by Sadebeck the asci are 25 long by 8–10 in diameter, which agrees quite well with the specimens on *P. pennsylvanica*, though on the latter some specimens measure 30 long, but the average is near 25. The stalk cells are 6–8 high by 7–9 in diameter and taper in many cases a little below, and then frequently intruding slightly between the cells of the epidermis. The measurements given for the stalk cells by Sadebeck are slightly larger, being 8 high by 8–10 in diameter. Aside from these slight variations it agrees very well with Sadebeck's species. It was first described by Sadebeck* from specimens on *Prunus insititia* and was later found by him on *Prunus domestica*. It forms "witches brooms" on both these trees in Europe.

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* Unters. ü. d. Pilzgattung Exoascus etc. Abgedruck, a. d. Jahrb. d. Hamb. Wiss. Anst. p. 113, 1884.

Kritische Unters. ü. d. durch Taphrina-Arten etc. Ibid, VIII, p. 27, 1891.

Die parasiten Exoasceen. Ibid, X, 2, p. 48, 1893.

PRUNUS DOMESTICA L. Plum.

Exoascus pruni Fuckel.

This fungus forms the well known "plum pockets," or "plum bladders" on the fruit *Prunus domestica*, the common cultivated plum. The mycelium is perennial in the fruit bearing branches and from these places grows out into the young ovaries in the spring. All or nearly all parts of the ovary are affected and the fungus stimulates the tissue of the ovary so that a remarkable hypertrophy occurs. The tissues become dry and spongy, the form of the plum being considerably enlarged. No stone is developed in the diseased plums and the interior is hollow and frequently traversed by loose threads of torn tissue. All of the plums on an affected tree are not usually affected, though I recollect seeing a tree in Chapel Hill, N. C., in the spring of 1886, on which there was not a single plum free from the disease. Frequently there are plums unaffected in the same cluster with the diseased ones.

The asci are very closely crowded together and frequently may develop quite irregularly, a few pushing through the cuticle first, followed later by others. A section of an affected fruit at this time would then show some asci very long and mature while others are not quite mature and the spores undifferentiated. There are many cells of the hymenium intermingled with the asci. The asci measure, in specimens which I have seen on *P. domestica* from Wisconsin, 30–60 long by 7–10 in diamter, and the stalk cells 15–22 high by 3–7 in diameter are rounded, or rarely pointed below. The longer asci are nearly cylindrical and many of the shorter ones slightly clavate. The spores are oval to elliptical, and from 3.5–5 in diameter. The measurements given by Sadebeck show a greater diameter, the ascus reaching a diameter as high as 15, and the stalk cell being given as 8 in diameter.

Robinson* speaks of a dimorphism in the asci, the slender ones being 43–60 long and 5.5–7 in diameter, while the stouter ones were 27–35 long by 9–12 in diameter. The size of the stalk cells he gives as 12–18 high by 5–8 in diameter. He also notes the fact that nearly all the asci which he examined were more slender

* Notes on the genus Taphrina. Ann. Bot. I, p. 166-7, 1887-8.

in proportion to their length than those described by Sadebeck. I have seen specimens probably of this species on *Prunus domestica* in North, and South Carolina, but unfortunately did not preserve any of them.

The shoots of *Prunus domestica* are sometimes deformed and enlarged bearing mature asci, the structure somewhat resembling that on the twigs of *Prunus angustifolia* Marshall. Prof. Halsted sent me some specimens collected at Manalapan, N. J. They are very old and overrun by some species of *Gloeosporium* so that it is not safe, it seems to me to attempt to decide what the species is. Some of the asci are illustrated in fig. 69.

PRUNUS SEROTINA Ehrhart. Black Wild Cherry.

Exoascus farlowii Sadebeck.

The ovaries of *Prunus serotina* are deformed by this species, the fruit becoming a spongy mass of tissue which is hollow within much as in the case of the fruit of *P. domestica* when affected by *E. pruni*. The ovaries are proportionately much more elongated, spindle shaped and curved, the end usually tapering to a long point. The floral envelopes are also hypertrophied and become persistent, which is not the case with *E. pruni* on the fruit of *P. domestica*.

The species was first described by Sadebeck* in 1890, from material collected by Dr. Farlow at Cambridge, Mass. In the material which Sadebeck examined he found the asci not crowded, but separated from each other, and this peculiarity, along with characters of the ascus and stalk cells, caused him to separate it from *E. pruni*, to which it had doubtfully been referred.† The distant asci, especially in the material examined by myself, does not seem to be a constant character, or even a frequent one, and I have examined quantities of material from Alabama, some from Canada, and some from Cambridge, collected by Dr. Farlow, and also by Halsted. The characters given by Sadebeck must then

* Kritische Unters. ü. d. durch Taphrina-Arten, etc. Ab. a. d. Jahrb. d. Hamb. Wiss. Anst. VIII, p. 30, 1891. See also Die parasiten Exoasceen, Ibid, X, 2, p. 47, 1893.

† Robinson, Notes on the genus Taphrina, Ann. Bot. I, p. 167, 1887-8 Ellis' N. A. F. No. 298. Here it is called E. pruni.

be modified so as to include the specimens with closely crowded asci. It is possible in specimens where the hymenium has not become evenly distributed over the surface that a section would show some asci which were considerably separated. But not taking this character into consideration I should consider it a distinct species from *E. pruni*. In 1889 I found a small quantity of this species in South Carolina, at Columbia. During the years 1890–93 I observed it as very common in Alabama, at Auburn. Quite large trees would have nearly all the fruit destroyed each year by it.

The asci are cylindrical and rounded or truncate at the free ends. They measure 20–33 long by 8–12 in diameter. The stalk cells are 12–20 high by 8–12 in diameter, averaging about one-third the length of the entire fruit body. These measurements give a greater diameter than that given by Sadebeck, 8–9 being the diameter given by him for the asci and stalk cells. The stalk cells frequently taper somewhat below and intrude themselves slightly between the cells of the epidermis at times. The mycelium I have not found to be so abundant in the tissues as is the case with *E. pruni* on *P. domestica*. The spores are more constantly rounded in form being approximately spherical, and are 3–4 in diameter. See figures 34–36.

Exoascus varius n. sp.

The leaves of *Prunus serotina* are frequently affected with a species of *Exoascus* which produces a folding or arching of the leaf. During the years 1890–3 I observed this to be very common and injurious on many trees in Alabama. In fact the same trees which were affected with the *E. farlowii* on the fruit had their leaves also badly affected. The shoots also were much deformed and sometimes enlarged, but there was not observed any tendency to the formation of "witches' brooms." Nor were any of the twigs observed to bear the asci. The deformity of the twigs or shoots occurred at the ends of the leafy branches, the leaves of the same being also diseased. Figures 13 and 14 are from photographs taken from living specimens. The deformity of the leaves and ends of the branches can be well seen. It is quite remarkable that the fruit of the same branches is also

affected, and this is well shown in the same illustrations. Large trees, thirty and forty feet in height, presented a very interesting sight and were noticeable for a considerable distance on account of the defective foliage, and especially from the brown and dead colors which succeeded the dying of badly affected leaves. The two forms, the one on the fruit and the one on the leaves, were so common on the same trees and so closely associated that many times I have been strongly inclined to consider them one and the same species. This inclination has been strengthened by a study of the structure of the fungus, for in many cases the asci and stalk cells on the leaves are very much like those of *E. farlowii* on the fruit, as can be seen by a reference to figures 26–31. In fig. 26 the asci measure 20–27 long by 8–10 in diameter and the stalk cells are 12–17 high by 8–10 in diameter. These are the largest ones which I have noted and they come very near to typical ones of *E. farlowii* on the fruit. In fig. 27 the asci and stalk cells possess the same proportionate lengths, but the entire fruit body is shorter, while the width is the same. Specimens occur, however, in which the proportion between the length of the ascus and stalk cells is different and the stalk cell may be only one-fourth as long as the entire fruit body instead of one-third, and the relation of the form to that of *E. deformans* becomes more apparent. But at the same time the stalk cell preserves quite constantly the same or nearly the same diameter as the ascus, and in a larger number of cases it is much longer than that of the latter species. Specimens on the leaves from Smyrna, Del., communicated by Mr. J. B. Ellis, present much the same characters, and some of the variations are illustrated in figs. 30, 31. Specimens on the leaves from Temple, N. H., collected by Mr. A. B. Seymour, also agree in these characters, as shown by some of the asci illustrated in fig. 32. The spores are rounded and four to eight in an ascus.

A form similar to this I collected at Columbia, S. C., in the spring of 1889. A few leaves of a shoot which grew from the base of a large tree were affected. Unfortunately these specimens are now lost. On the same tree, but not near the affected leaves were a few of the fruits affected by *E. farlowii*. I should still be strongly of the opinion that the fungus on the leaves of *P. serotina*

were but a leaf form of *E. farlowii* if it were not for the fact that I have observed two very different species of *Exoascus* growing in very close proximity to each other on the same tree, so close in fact that it is quite probable the mycelium of the two was intermingled in the branch which bore the affected fruits and leaves. These occur on *Prunus americana* under which paragraph the description of the species will be found. Another reason for considering them distinct species is the probable fact that usually a certain species quite constantly exercises a peculiar physiological influence upon the host, and that if the form on the leaves and twigs of *P. serotina* described here were the same species as that which occurs on the fruit of the same tree, we would expect it to produce a spongy abnormal growth in the buds and ends of the branches just as *Exoascus mirabilis* Atkinson does in the buds of *Prunus augustifolia*. For these reasons and from the fact that the fungus departs too widely from the characters of *Exoascus deformans*, it seems best to consider it as a distinct species, and I propose the name *E. varius* for it on account of the variable proportion which exists between the length of the ascus and stalk cell.

PRUNUS MARITIMA WANG. Beach Plum.

Exoascus communis Sadebeck.

This species affects the fruit of *P. maritima*, causing the plum "pockets." The specimens which I have seen were collected by Dr. Farlow at Dartmouth, Mass. Sadebeck* has recently described this species as occurring on this host as well as on *P. pumila* L. and *P. americana* Marshall, all from the United States. The structure of the asci and the relation of the stalk cells to the epidermis is represented in fig. 58. The asci are slender, rather slightly clavate, and rounded or somewhat truncate at the free ends. Sadebeck gives the measurements for the species as follows: The asci are 30–40 long and about 8 in diameter, the stalk cells 15 to 20 high by 3–5 in diameter. Although the stalk cells are often somewhat pointed below he says they do not intrude between the cells of the epidermis. The measurements I have taken from the asci on *P. maritima* vary but little from

*Die parasitischen Exoasceen. Ab. a. d. Jahrb. d. Hamb. Wiss. Anst. X, 2, p. 47, 1893.

these dimensions, the asci being 25–45 long by 6–8 in diameter, and the stalk cells 15–25 long by 3–6 in diameter. They are somewhat pointed below and according to my observations do, to a slight extent, project between the cells of the epidermis, but not markedly so. The spores are rounded or oval in form and are 3–4 in diameter.

PRUNUS NIGRA AITON. Wild Red Plum.

Exoascus communis Sadebeck.

Fruits of this plum distorted into the usual "pockets" or "bladders," collected by C. H. Davis, at Alma, Mich., June 2, 1894, were communicated to me by Prof. L. H. Bailey. The fungus agrees with Sadebeck's *E. communis*. The asci measure 35–45 long by 7–9 in diameter, and the stalk cells 15–22 high by 4–6 in diameter. The stalk cells are frequently pointed below and occasionally intrude slightly between the epidermal cells as in *E. communis* on *P. maritima*. The structure of the fungus and the relation of the stalk cells to the epidermis is represented in fig. 60.

PRUNUS PUMILA L. Dwarf cherry.

Exoascus communis Sadebeck.

Exoascus communis is also described by Sadebeck on the dwarf cherry, *Prunus pumila* L. Mature conditions of the fungus on this plum I have not seen. The plum "bladders" were formed on the fruit of this species on some plants which are growing in the Horticultural grounds of Cornell University, in June, 1894. A photograph showing the form of these "bladders" and the normal fruit is represented in fig. 19. The surface of the swollen fruits is quite uneven, and the tissue is characteristic of similar tissues in other species of plums thus affected. These specimens unfortunately did not mature their asci.

PRUNUS ANGUSTIFOLIA Marshall. Chickasaw plum.

Exoascus mirabilis n. sp.

This remarkable species deforms the leaf buds and young twigs of *Prunus angustifolia* Marshall, the Chickasaw plum (*P. chicasa* Michz.). It also occurs on related species of *Prunus*. I observed it in the vicinity of Columbia, S. C., in May, 1889, and

during three years, 1890–92, I observed it as very abundant at Auburn, Ala., both on the wild *P. angustifolia* and its cultivated varieties. It produces in the young leaf buds and the ends of the young twigs an enlarged structure, the tissue of which is very much like that of the plum "bladders." The swollen bud or twig is usually whitish or yellowish white in color, the tissue is soft and spongy, and the structure is hollow at the center. They vary greatly in form, being clavate, oval, lanceolate, or elliptical; while the surface varies also to an equal extent, depending upon the stage of development of the bud or twig at the time that the growth is arrested. The bud may be brought well under contribution before the leaves have begun to open, when the large mass of tissue will present no appearance of even the leaf tips. Sometimes the leaves partly separate and then short or long points which are of the same kind of tissue will project from the bulk of the mass. Again, the leaves may be more or less expanded, so that some of them present green normal tips projecting from the swollen bud, and from this the green expanded portion varies through different specimens so that in some there are normal leaves standing out from it. Two of these conditions are reproduced from photographs of fresh specimens in figures 10 and 11, Plate V.

The asci are developed all over the surface of the spongy portion of the structure, and give it a mealy appearance. The twig is sometimes enlarged and deformed to some distance below the enlarged spongy end, and it is not rare to find, especially at a rather late period for the development of the asci, twigs slightly enlarged for a considerable distance, but bearing no asci. The fungus in structure is rather closely related to *Exoascus pruni*, and at one time I considered it identical with that species. Specimens collected by myself in Alabama were distributed by Seymour and Earle* as *Taphrina deformans* (Berk.) Tul.

The asci are slightly clavate, rounded or truncate at the free ends, and measure 25–45 long by 8–10 in diameter. The stalk cells are 10–18 high by 5–8 in diameter, and are usually rounded or truncate at the base. They do not intrude between the cells of the epidermis. The spores are quite regularly elliptical, or rarely

* Economic Fungi, No. 129.

oval, agreeing in this respect somewhat with the spores of *Exoascus rostrupianus** Sadeb. but not so large as in that species.

The mycelium is very abundant in the tissues of the affected buds, forming a very complex network of threads between the cells of the hypertrophied tissue. The details of structure are shown in figures 61 and 62.

The same fungus also occurs in Iowa, specimens collected on *Prunus angustifolia* (P. chicasa) in Chickasaw Co., by Prof. L. H. Budd, were communicated to me by Prof. L. H. Pammel.

The mycelium is perennial in the branches, and in the following spring the young buds from such branches are more likely to suffer from attack.

Exoascus mirabilis var. *tortilis* n. var.

This form occurs on the fruit of *Prunus angustifolia*, very rarely producing the plum "bladders," and then the fruit is only affected on one side and is strongly curved. Usually the attack is confined to a rather small area or so small that a considerable portion of the fruit retains its normal form and color, and it is not hollow within. The structure of the fungus is but little different from that on the buds, the chief differences being in somewhat larger development, so that the asci are somewhat longer and the stalk cells higher. The other characters, including those of the mycelium are the same as in the form on the buds. The propriety of separating the form on the fruit as a variety may be questioned, but it seems well to do so in order to avoid possible confusion, since the form on the buds is the more common one in localities where I have observed it, and quite frequently trees may present many buds which are affected when all the fruits are free from attack.

Erwin Smith† notes the occurrence of both these forms on *P. angustifolia* and its cultivated varieties in Maryland and Georgia. He suggests that it may be distinct from the *E. pruni*.

Many of the native trees are very seriously affected, and it seems in some cases to be spreading and becoming serious in the plum orchards in the southern states.

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* Die parasitischen Exoasceen. Ab. a. d. Jahrb. d. Hamb. Wiss. Anst. X, 1, p. 46, 1893.

† Jour. Mycology, p. 108, vol. VI.

Prunus hortulana L. H. Bailey.

Exoascus mirabilis. Atkinson.

The buds and ends of the branches of *P. hortulana* are affected exactly like those of *P. angustifolia*, and the fungus seems to be identical with the species on that plant. All of the specimens were communicated to me by Prof. Pammel. Some of the details of the asci, etc., are illustrated as follows. Fig. 70 from specimens collected at Ames, Iowa, in May, 1894; fig. 72 from specimens collected by Dr. A. B. Dennis at Cedar Rapids, Ia., May, 1894. These specimens which I examined were rather young and comparatively few of the asci were fully developed. Fig. 68 is from specimens collected by Mrs. R. M. Kellum, at Salem, Ia., June 8, 1894. In this specimen the asci and stalk cells were much longer than in any of the other specimens, though the relative proportions between the asci and stalk cells remain about the same. This specimen was marked "*Prunus chicasa*, 'Wild Goose Plum.'" Prof. Bailey has determined it as *P. hortulana*.

Figs 70 and 72 agree in all respects with the type.

Fig. 71 represents the asci and the relation of the fruit structures to the epidermal cells in specimens from the buds of *Prunus hortulana* var. *mineri*, also from Iowa, collected by A. Noe, in May, 1894. These also agree with the type on *P. angustifolia*.

Prunus americana Marshall. Wild Red Plum.

Exoascus longipes n. sp.

The specimens which constitute the type of this new species were collected at Danby, N. Y., by T. A. Mandeville. A photograph of the twig bearing numerous "bladders" and a normal fruit is reproduced in fig. 3, Plate II. The hypertrophied fruits are irregularly long ovate and sometimes slightly curved. The fungus is quite different from any of this class described hitherto on the fruits of *Pruni*. It is characterized chiefly by the very long stalk cells and from the circumstance that they intrude themselves prominently between the cells of the epidermis. The asci are slightly clavate and rounded or somewhat truncate at the free end. They are 30–40 long by 7–10 in diameter. The stalk cells are 25–35 high by 3–5 in diameter, being usually much narrower

below. The lower ends of the cells of the hymenium begin usually to intrude themselves between the cells of the epidermis at quite an early stage of development. Fig. 47 shows this relation of the cells of the hymenium to the epidermal cells. This results from a peculiarity of the development of the ascogenous cells from the first mycelium which spreads beneath the cuticle. The growth from these cells proceeds inward, that is, toward the epidermis, as well as outward in the direction of the formation of the ascus. This is quite markedly the case in all the long stalked species of *Exoascus* which I have examined, even of *E. pruni*, *E. communis*, *E. mirabilis*, and others. It is however much more marked in this species than in those just quoted, especially the long inward growth of the stalk cells. After many of the asci are quite well developed and are somewhat crowded, the hymenium continues to increase in a peculiar manner in all of these species but more so in some than in others. An ascogenous cell develops somewhat below the middle a slender branch which grows inward toward the epidermis. After having grown downward for some distance, sometimes having reached a length of 15–20, the outer end begins to grow outward to form the ascus. A series of these with a young ascus is shown in fig. 49. In this way the lower ends of the stalk cells will frequently be at a very irregular line, some of them not intruding between the cells of the epidermis while others are crowded far down between them. *Exoascus rostrupianus* probably develops the later hymenium in this way to judge from Sadebeck's description, and also from the fact that it is a long stalked species. But according to Sadebeck* the stalks do not intrude themselves in the least between the epidermal cells. The spores are also quite different, being quite constantly elliptical, and the conidial formation from budding of the spores in the ascus being very rare. The spores in *E. longipes* are round or oval, measuring 3–4 in diameter.

When the asci are developing from these later hymenial cells it frequently happens that the septum separating the stalk cell from the ascus is formed below the connection of the fruit body with its neighbor from which it had its origin.

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*Die parasitischen Exoasceen. Ab. a. d. Jahrb. d. Hamb. Wiss. Anst. X, 2 p., 29, 1893.

The mycelium is very abundant in the tissues of the hypertrophied fruits, forming a well developed network of threads between the cells as in other species of this type.

These are the only specimens on *P. americana* Marshall of this species which I had the opportunity to examine. Other specimens of hypertrophied fruits of *P. americana* were collected near Ithaca, N. Y., during June, 1894, and judging from a photograph which I have seen of them the form of the hypertrophied fruit is quite different. The specimens have either been mislaid or lost so that at this time there is no means of examining them to see whether they belong to this species or to *E. communis* Sadebeck.

Exoascus communis Sadebeck.

Sadebeck* reports this species on *Prunus americana* Marshall from the United States, collected by Bartholomew. To it I have also referred specimens collected by Seymour at Madison, Wis., June 3, 1886, and distributed as *Taphrina pruni*† (Berk.) Tul.

Specimens on the fruits of cultivated varieties of *P. americana* communicated by Prof. Pammel, and collected in Iowa, show a much distorted fruit in many specimens, especially of the "Cheny" variety. In some of these fruits only one side appears to be affected, resembling in this respect very much, the fruits of *P. angustifolia* deformed by *E. mirabilis* var. tortilis Atkinson. The form of the stalk cells also seems to be nearer those of that species than of *E. communis*, and I do not feel like definitely locating the form until we know more about the relation of these hypertrophied fruits of the cultivated varieties of *P. americana* to the deformed buds which also occur on *P. americana*, and which appear to be identical with those on *P. angustifolia* and *P. hortulana*.

The asci of the "Cheny" and "Baldwin" varieties of the form on the fruit of *P. americana* are shown in detail in figures 40–43, 42 representing the asci of the Baldwin variety.

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* Die parasitischen Exoasceen. Ab. a. d. Jahrb. d. Hamb. Wiss. Anst. X. 2, p. 47, 1893.

† Seymour and Earle, Economic Fungi, No. 13.

Exoascus mirabilis Atkinson.

To this species I refer the form on the buds of *P. americana* Marshall, from Iowa, specimens communicated by Prof. Pammel, and by Prof. Seymour. The asci, stalk cells and spores are shown in figs. 68 and 69.

Specimens of probably this same species on the buds of the Maquoketa* plum were reported from Iowa in 1888, the Maquoketa being here inadvertently referred to the Chickasaw plum.

Exoascus decipiens n. sp.

This species distorts the leaves and young shoots of *Prunus americana* Marshall. Specimens have been collected at Danby, N. Y., by T. A. Mandeville, and at Aetna, N. Y., by the writer. A photograph of two of the specimens from Danby are reproduced in figs. 5 and 6, Plate III. The young shoot is somewhat enlarged, though there are developed no asci on any of the shoots which I have seen. In fig. 5 some of the leaves can be seen to be finely wrinkled near the base. The affected part of the leaf is usually thrown into a series of very fine folds or wrinkles, and the under surface, which at the time of the maturity of the asci is frequently farther injured, presenting a scurvy appearance, is covered by scattered groups of rather loosely associated asci. No asci have as yet been found upon the upper surface, and from careful examination I have not been able to detect any development corresponding to the "witches brooms," so that the species seems to be well differentiated from *E. insititiae* Sadeb. The asci are also much larger and different in other respects than those of that species. They are nearly cylindrical and rounded or rarely truncate at the free ends, and measure 20–40 long by 7–10 in diameter. The stalk cells are quite broad, frequently broader than the asci, and measure 6–13 high by 7–12 in diameter. They are usually rounded below, but sometimes are pointed much as in *E. deformans* on the peach. The spores are oval or broadly elliptical, measuring 3–4 in diameter. Quite frequently conidia are developed by budding while still within the ascus.

* Report Dept. Agr. p. 368, 1888.

Where the leaves are fully expanded or nearly so before they are seriously attacked the injury is confined chiefly to the base of the leaf and the petiole. Sometimes isolated spots nearer the tip of the leaf are also affected. If the leaves are seriously attacked when quite young they become killed, still clinging to the branch and with no development of asci dry, become crisp, and black. The blades of leaves only partially affected also become black, the lamina first and the petiole later, especially when the serious attack is chiefly confined to the base of the leaf. This dying of the affected parts often continues into the shoot, which presents also a blackened appearance. One of these shoots with blackened leaves in different stages of development is reproduced from a photograph in fig. 17, Plate VIII.

The mycelium is perennial in the young branches, and occurs in the intercellular spaces of the affected parts.

See figurus 74–77, Plate XIX, for details.

Fig. 5, Plate III, shows also the fruits of *P. americana* deformed by *Exoascus longipes* Atkinson, growing from the same shoot as *Exoascus decipiens* and very near it. In the shoot the mycelium of the two species is probably somewhat intermingled, but there can be no doubt about the two being different species, for they represent very remote types of *Exoascus*.

Exoascus decipiens var. *superficialis* n. var.

On half formed fruits of *Prunus americana* Marshall, at Aetna, N. Y., I have found an *Exoascus* which may prove to be a distinct species. I have not had as yet sufficient material to give it the careful study to determine this point. I therefore prefer at the present to place it as a variety of *E. decipiens* Atkinson, especially as it occurs in the cases thus far observed on the same tree on which I collected *E. decipiens* at Aetna, N. Y. The first specimens were collected July 6, 1894. At this time the *E. decipiens* on the leaves had nearly disappeared, at least the fruiting condition of it. The fungus on the fruit at this time was not mature, but was collected in a mature condition on July 28. The fruits as stated above are half formed and the stone is normal, or at least not wanting. For this reason I have proposed the name *superfi-*

cialis. On the affected parts the mycelium penetrates to some depth, however, in the tissue and warty swellings appear, or a large part of the surface is laid under contribution to the fungus. Two of these hypertrophied fruits showing the extremes of this condition are reproduced in fig. 7, Plate III.

On the specimens which were collected July 28, the surface of these warty projections was roughened and finely cracked, and beside the mature asci which were present there were other fungi of a saprophytic nature, especially a specimen of Cladosporium, though not in profusion. The hymenium was upon the surface of this tissue. The asci are about 25–30 long by 8–11 in diameter, and some of them presented a constriction near the base. The stalk cell in the specimens seen were very short, but farther study is necessary to determine these characters. The asci, however, are near the type of those on the leaves. Whether the mycelium is perennial in the branches and grows out into the fruits, or whether infection takes place by spores from the species on the leaves cannot at this time be stated. If the former were the case there would seem good ground for considering it as a distinct species.

PRUNUS TRIFLORA Roxburgh. Japan Plum.

Exoascus rhizipes n. sp.

This very interesting species was collected by the writer on Japan plums of the variety sometimes called Botan, or Botankio. It was collected at Auburn, Ala., May 1, 1892. Superficially the hypertrophied fruit and buds resemble those on the Chickasaw plum (*P. angustifolia*). One specimen, in which an affected fruit and bud were growing very close together on the same branch, was photographed and is reproduced in fig. 4, Plate II.

While the superficial resemblance is close to the hypertrophies caused by *E. mirabilis* Atkinson, the structure of the fungus is very different, and also differs markedly from any described species. It is more closely related to *E. longipes* Atkinson, but differs from that in the stalk cells which intrude much farther between the cells of the epidermis and by the frequent development of numerous rhizoids which are intermingled with the stalk cells and also penetrate between the epidermal cells. The lower part of

the slender stalk cell is frequently septate as are also the rhizoids. The stalk cells of *E. longipes* occasionally possess a few rhizoids, and this is the case in many of the long stalked species, but the occurrence on those species is rare. These rhizoids are developed both from the stalk cells and from the lower part of the ascus. Their origin is related, or similar in kind, to that of the development of the later portions of the hymenium in this and other species noted under the discussion of *E. longipes*.

A very thin section presents the appearance as if there were no stalk cells whatever, but that the asci arose from a very complex cellular hymenium of several layers in thickness, the inner layers of which are between the epidermal cells of the host.

The typical form is on the fruit and the structure of the asci and the relation of the stalk cells is shown in Plate XV, figs. 53–57. Some young developing asci from the fruit are shown in fig. 57, with a few rhizoids and young hymenial cells. The older asci are difficult to tease out well from their attachment in the epidermal cells so as to preserve all the rhizoids in situ. The asci are slightly clavate, are 30–40 long by 8–10 in diameter. The stalk cells reach a length of 25–35 or 40, and are 3–5 in diameter. The rhizoids and stalk cells as well are frequently septate. This occurs sometimes also in *E. longipes* but rarely compared with the occurrence in this species.

The young cells of the hymenium also more early intrude themselves between the cells of the epidermis. The intercellular mycelium is abundant as in the other related species. The spores are elliptical.

The form on the buds is similar, but the development of the rhizoids is not so profuse, nor are they so long. This may be accounted for I think from the fact that the fruit forms a more suitable nourishment and all the structures are forced to a greater development. The same relation exists between the form on the fruit in *E. mirabilis* and that on the buds, but in each case it is quite easy to properly correlate the two forms. On the bud the stalk cells intrude themselves far between the cells of the epidermis, as shown in fig. 53. In fig. 55 are shown three asci with their stalk cells and the connection near the septum dividing the stalk from the ascus.

PRUNUS VIRGINIANA L. Choke Cherry.

Exoascus confusus n. sp.

The fungus causing the hypertrophied fruits of *Prunus virginiana* have been referred, it seems to me improperly, to *Exoascus pruni*. Sadebeck* considers it identical with the *Exoascus* causing the hypertrophied fruits of *P. domestica* and places it in *E. pruni*. The asci are quite different and especially the stalk cells and their proportion to the asci. Figures 37–39, Plate XII, represent the details of these structures. Fig. 37 is from a rather young specimen from Forest Home, N. Y., and figs. 38, 39, from specimens collected by Underwood at Taburg, N. Y., communicated by Seymour. Comparing these figures with those of *E. pruni* from *P. domestica*, shown in figs. 44, 45, a great difference is seen. All of these illustrations of the structure of the asci, etc., are carefully drawn with the aid of the camera lucida to the same scale, so the comparison can well be made from the illustrations. The asci of this species on the fruit of *P. virginiana* are, according to these specimens, 30–45 long by 8–12 in diameter. The stalk cells are 15–30 high by 6–10 in diameter. The stalk cells are nearly or quite the same diameter as the asci and are proportionally longer than those of *E. pruni* on *P. domestica*, and Sadebeck† says upon examination that the fungus upon the fruit of *P. domestica* in the United States is the same as that in Europe upon the same host. The stalk cells also on the fruit of *P. domestica* are also more slender in proportion to the diameter of the ascus than in those on the fruit of *P. virginiana*.

The physiological effect upon the host is also quite different. Not only is the hypertrophied fruit much longer in proportion to the diameter than is the case with the fruit of *P. domestica*, but the floral envelopes are also constantly hypertrophied and become persistent, which is not the case with the same organs of the flower of *P. domestica*. The asci are also developed on the floral organs.

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* Kritische Unters, etc. Ab. a. d. Jahrb. d. Hamb. Wiss. Anst. VIII, 29, 1891.

† Die parasitischen Exoasceen. Ibid. X, 2, p. 44, 1893.

Robinson* calls attention to the fact that the asci on the fruit of *P. domestica* are much more slender than the measurements given by Sadebeck would indicate. In a later contribution Sadebeck† himself indirectly gives some ground for considering this a distinct species from the *E. pruni* on *P. domestica*. In this communication he thinks it possible that a careful examination of the fungus on the fruit of *Prunus padus*, which he previously studied and placed in *E. pruni*,‡ may prove to be a distinct species. The hypertrophied fruits of *P. padus* agree in external appearance more nearly with those of *P. virginiana* than with those of *P. domestica*, and the floral organs of *P. padus* are also hypertrophied. *Prunus padus* and *P. virginiana* both belong to the same type of the genus *Prunus* and to a different type from that to which *P. domestica* belongs.

I should consider the fungus on *P. virginiana* much more nearly related to the *E. farlowii* on *P. serotina* than to *E. pruni*. The relative size of the asci and stalk cells as well as the proportionate length of the same, suggest this, as can be seen by comparing the illustrations of the two. Figs. 34–36 being those of *E. farlowii* and 37–39 being those of the species on the fruit of *P. virginiana*. There are, it seems to me, however, good specific differences between these two, the base of the stalk cells in *E. farlowii* being frequently narrower and running to a point which intrudes somewhat between the cells of the epidermis. The asci of *E. farlowii* are also much shorter, and the stalk cells are proportionately a little broader. I therefore propose for the fungus on the fruit of *P. virginiana*, the name, *Exoascus confusus*.

Exoascus cecidomophilus n. sp.

This is a very interesting species which I have found upon the fruits of *Prunus virginiana* which were deformed by a species of *Cecidomyia*. The species was discovered too late in the season to say whether the larvæ attacked the fruit before or after the attack by the fungus. I believe at this time, however, that the cecidomid larvæ attack and deform fruits which are not affected by the

* Notes on the genus Paphrina. Ann. Bot. I, p. 168, 1887–8.

† Die parasitischen Exoasceen. Ab. a. d. Jahrb. etc. X, 2, p. 45, 1893.

‡ Kritische Unters. etc. Ibid. VIII, p. 29, 1891.

fungus. Certainly the larvæ control to the greater extent the form of the gall, which is very different from that produced by any hitherto known species of the *Exoasceae*. Neither the floral envelopes nor the stamens suffer hypertrophy, the carpel alone being concerned. This is transformed into a peculiar hollow and open gall, the opening being at the base of the ovary and appearing as if it were formed by the cracking away of a portion of the base from the receptacle, as the base of the fruit by hypertrophy increases in size. The peculiar shape of the gall is shown in figs. 15 and 16, Plate VII, reproduced from a photograph. They are from 1.5–2.5 cm. long and somewhat less than 1 cm. in diameter, being two to three times longer than broad. They are somewhat broader than the normal fruit and two to four times longer, as can be seen in the illustration in which are shown a few normal fruits attached to the same cluster. Sometimes only one or two of the fruits in a raceme are affected. This trouble seems to be a very common one in the vicinity of Ithaca, N. Y. It is especially abundant along the Dryden road between Aetna and Varna, where it was first noted by Prof. J. H. Comstock. The gall is nearly oblong in outline, with rounded ends, a slight inflation at the middle and a constriction near the base, so that the very base seems to flame outward as if inverting. It is also more or less curved.

The fungus does not occupy the entire gall and does not penetrate to a very great depth in the tissues, while the mycelium is rather scanty. Sections, however, do show that the mycelium penetrates in the subepidermal tissue to some extent between the cells over a portion of the gall. The side of the gall which is affected by the fungus is more strongly arched than the unaffected side. Whether the slight curve which has thus far been observed to be present to some extent in all the galls examined, is caused by the presence of the mycelium, has not yet been determined. Several have been examined and the mycelium not found, but farther study is necessary to determine this point, and also to determine the exact relation of the cecedomid to it.

Before the galls die if they are cut open, several of the reddish larvæ of the cecidomid will be found inside clustered at the apex of the hollow interior. The cavity is quite large and smooth, and of a dark color.

The tissue of the gall is quite hard, especially so as compared with that of the ordinary "bladders" formed by species of *Exoascus*, and this taken with the scanty mycelium of the fungus and the peculiar shape of the gall is pretty strong evidence that the form of the gall is more strongly influenced by the cecidomid than by the fungus.

The fungus is very different from those which are known to produce the "bladders" or "pockets" of the fruits of *Prunus*. The asci are cylindrical or slightly clavate and rounded at the free ends. They are 30–40 long by 6–10 in diameter. The stalk cells are very broad, being 6–10 high by 10–15 in diameter. They are usually rounded and blunt below and do not at all intrude between the cells of the epidermis. The asci are scattered or rather loosely aggregated. Figs. 73, 78, 79, illustrate the asci, etc., of this species. The spores are rounded or elliptical, and very frequently the formation of conidia by budding in the ascus takes place. In a few cases I have observed the spores in process of formation before the wall separating the ascus from the stalk cell was formed. Two such cases are represented in fig. 73. One case was observed where no wall was formed even when the ascus was mature and the spores occupied the entire fruit body. A few variations of this kind have been observed in some of the other species. Sadebeck records a case of the beginning of spore formation before the separating wall was developed.

Occasionally on the same trees which bear the cecidomid galls with the *Exoascus cecidomophilus* Atkinson, are the old mummified hypertrophied fruits caused by *Exoascus confusus* Atkinson (*E. pruni* of Authors). Fig. 16, Plate VII, shows a very interesting condition of the fruit which is sometimes seen. A single raceme bears several normal fruits, one mummified fruit the result of the attack of *E. confusus* in May or early June, and several fruits attacked both by a cecidomid and by *E. cecidomophilus* in July.

Exoascus sp

A species of *Exoascus* has been found deforming the leaves and twigs of *Prunus virginiana*, but thus far I have not seen the mature condition though several diligent searches have been made for it. To what species it belongs or whether the one in the

shoots is the same as the one in the leaves is not known. A few shoots on one tree by the roadside near Crowbar Point on the west shore of Cayuga Lake were found by me on June 28, 1894. They were enlarged for some distance from the ends and the greater diameter of the hypertrophied shoot was some distance from the end. They were also curved to one side by torsion, usually nearly at a right angle, but in one case the torsion had continued until the shoot made an entire revolution and the end then pointed in nearly the same direction as the main part of the shoot. This one is reproduced in fig. 18, Plate VIII. Some of the leaves of these same shoots were deformed by a species of *Exoascus*. Somewhat similar distortions of the leaves were found along the Dryden road between Aetna and Varna, July 6 and 28. A few only were found on a very few of the shrubs which also possessed the cecidomid galls. None of the shoots here were deformed. An examination of the tissues of the shoots and and leaves thus deformed showed the presence of the mycelium of an *Exoascus*.

Fig. 84 represents the intercellular mycelium in a twig, and fig. 80 the mycelium and very early stage of the formation of the hymenium in a petiole of a very young leaf in a bud of the same.

PRUNUS DEMISSA Walp.

Exoascus varius? Atkinson.

Among other specimens communicated to me by Prof. Pammel was one from the Herb. of Prof. Wm. Trelease, collected in Ute Pass, Colorado, on the leaves of *Prunus demissa* Walp. The affected spots appear to have been arched and slightly folded, forming rather shallow open pockets, much like those which I have here observed on the leaves of *Prunus virginiana*, to which *P. demissa* is closely related. In the specimens observed the asci were developed on the upper surface of the leaves forming a whitish coating to the spots. Some of the asci are illustrated in fig. 33. Without more material and fuller observations I do not care to definitely locate the species. It is marked *Taphrina deformans*. It seems to me that the proportion existing between the length of the stalk cells and the asci is different from that in the specimens on the peach, and agrees more closely in that respect

with the fungus on the leaves of *P. serotina* L. which I have referred to *E. varius* n. sp. I would therefore provisionally refer it to that species.

CONCLUSIONS.

It is to be regretted that definite and conclusive experiments have not yet been made concerning the treatment and control of the diseases caused by the various species of the *Exoasceæ*, so that this information, which is most desired by fruit growers could be here confidently placed before them. It is hoped, however, that this contribution will give those interested a greater familiarity with the characteristics of the deformed leaves, fruits, and branches caused by this group of parasitic fungi and that this will lead to a more intelligent line of experimentation.

It should be remembered that the species possess a perennial mycelium which lives in the buds or branches of the trees, during the winter months, of plants which once have become infected. That a tree once affected is likely to show the disease more or less every year. Climatic conditions probably influence a greater or less injury from year to year, so that in some years little of the trouble may be observed when in other years it is more common. This has led some to suppose that the fungi are not perennial, but that a fresh infection each year is caused by the spores only. This is a mistake. There is abundant evidence from the results of several investigators to show that the mycelium is perennial, for it has been found during the winter months, and in the spring has been traced as it grows from the buds or branches into the young leaves or fruits. It is quite possible that one source of the original infection of trees is from the attacks of spores. I have several times attempted to inoculate healthy peach trees, or unaffected ones, from the spores taken from freshly mature specimens on affected trees. This I attempted at Auburn, Ala. Not only were spores sown on the young leaves and buds, but pieces of the leaves containing mature spores, and others containing the mycelium only were inserted into a slit in young buds and in the young branches near buds. In no case did any sign of the disease appear even after three years. Several of these incisions

were wrapped with moist cloth and kept moist for several days, while in other cases a moist chamber was made around the twig by covering it with quite a large test tube. Had young buds been inserted in the manner of budding during the month of August in all likelihood the disease would have appeared in a year or two. I know of no successful experiments made in inoculating peach or plum trees from the spores, although such results may have been attained. It is usually considered by most students of this group that it is rather difficult to secure results from the inoculation by spores in many of the species of *Exoascus* while in others it is comparatively easy. Sadebeck* succeeded in inoculating *Alnus incana* with the spores of *Exoascus epiphyllus*, and producing the characteristic disease. He says it is easier to produce an infection with this species than with any other of the species of *Exoascus* known to him.

Since the mycelium is perennial in the buds or young branches of affected trees no buds should be taken from such trees for budding nursery stock or budding in the orchard. Since nearly all of the affected leaves of the peach trees fall away before the time for the selection of buds, the trees should be carefully selected in the months of May and June in order to avoid those which have the disease.

Where only a few branches of a tree are affected, pruning a considerable distance below the affected portion might be tried, especially in the case of those plum trees affected with *E. mirabilis*, that is those having the bud deformations.

It may be well in concluding to give a list of the species of *Exoascus* described here as occurring on species of Prunus in the United States, with their host.

Exoascus deformans (Berk.) Fuckel, deforming the leaves and rarely the shoots of *Prunus persica* L.

Exoascus pruni Fuckel, deforming the fruit, causing "bladders" or plum "pockets" of *Prunus domestica* L.

Exoascus insititiæ Sadebeck, causing "witches brooms" and deforming the leaves of *Prunus pennsylvanica* L.

Exoascus cerasi (Fuckel) Sadebeck, causing "witches brooms" and deforming the leaves of the same on *Prunus avium.*

* Kritische Unters, etc., 1891.

Exoascus confusus Atkinson, deforming the fruit and floral envelopes of *Prunus virginiana* L.

Exoascus farlowii Sadebeck, deforming the fruit and floral envelopes of *Prunus serotina* L.

Exoascus communis Sadebeck, deforming the fruits of *Prunus maritima* Wang., *P. pumila* L., *P. americana* Marshall, *P. nigra* Aiton.

Exoascus longipes Atkinson, deforming the fruit of *Prunus americana* Marshall.

Exoascus mirabilis Atkinson, deforming the leaf buds and twigs, forming "pockets," of *Prunus angustifolia* Marshall, *P. hortulana* L. H. Bailey, *P. americana* Marshall.

Exoascus mirabilis Atkinson var. *tortilis* Atkinson, distorting the fruit of *Prunus angustifolia* Marshall.

Exoascus rhizipes Atkinson, deforming the fruit and leaf buds of *Prunus triflora* Roxburgh.

Exoascus decipiens Atkinson, deforming the leaves and shoots of *Prunus americana* Marshall.

Exoascus decipiens Atkinson var. *superficialis* Atkinson deforming the surface of the fruit of *Prunus americana* Marshall.

Exoascus varius deforming the leaves and shoots of *Prunus serotina* L. and ? *P. demissa* Wang.

Exoascus cecidomophilus Atkinson, affecting cecidomid galls on the fruit of *Prunus virginiana* L.

GEO. F. ATKINSON.

NOTE. I wish to acknowledge my great indebtedness to the following persons who have aided me chiefly by the communication of material: Prof. L. H. Pammel, Prof. A. B. Seymour, Prof. T. Meehan, Prof. B. D. Halstead, Mr. J. B. Ellis and Mrs. Flora W. Patterson.

EXPLANATION OF THE PLATES.

All the illustrations in Plates X–XIX inclusive were drawn with the aid of the camera lucida to the same scale. One millimeter of the eye piece micrometer scale of this combination is drawn in each plate. The figures are magnified 30 times more than this scale.

Plate I. Exoascus deformans (Berk.) Fuckel, on leaves of Prunus persica (L.), peach. Fig. 1 from Ithaca, N. Y. The petioles and a portion of the stem are here also affected. Fig. 2 from Auburn, Ala.

Plate II. Fig. 3, Exoascus longipes Atkinson, in fruits of Prunus americana Marshall. One young plum at the right is sound and serves for comparison with the hypertrophied fruits. From N. Y.

Fig. 4, Exoascus rhizipes Atkinson, on fruit and bud of Prunus triflora Roxburgh, Japan plum. From Auburn, Ala.

Plate III. Figs. 5 and 6 Exoascus decipiens Atkinson in the leaves of Prunus americana Marshall. In 6 the shoot is deformed. In 5 the fruits are deformed by E. longipes Atkinson. From N. Y.

Fig. 7, Exoascus decipiens var. cecidomophilus Atkinson in half grown fruits of Prunus americana Marshall. The plum at the left shows but a few warty excrescences, while the one at the right is affected over a large part of the surface. From Aetna, N. Y., on the same tree on which E. decipiens was collected. Fig. 17 in Plate VIII is E. decipiens Atkinson from the same tree, on which the plums in fig. 7 were collected.

Plate IV. Exoascus mirabilis Atkinson var. tortilis Atkinson, in fruits of Prunus angustifolia Marshall (P. chicasa Michz.). Only one side of the fruit is attacked. In each figure one healthy and one affected fruit is shown. From Auburn, Ala.

Plate V. Exoascus mirabilis Atkinson in buds of Prunus angustifolia Marshall. In figure 10 several of the leaves were fully expanded before the bud was severely attacked. Fig. 12 Exoascus mirabilis var. tortilis Atkinson on fruits of P. angustifolia Marshall. All from Auburn, Ala.

Plate VI. Exoascus farlowii Sadebeck, in carpels of Prunus serotina L. Some of the carpels are not attacked and the flowers form a means of comparison with the affected ones. From Auburn, Ala.

Exoascus varius Atkinson, in the leaves and shoots of the same branches. The shoots are deformed and enlarged at the ends but are not developing "witches' brooms."

Plate VII. Exoascus cecidomophilus Atkinson, in fruits of Prunus virginiana L. deformed by cecidomid larvæ. In fig. 16 the strongly arched sides of the galls are the places where the Exoascus is located. Midway of the raceme is a mumified fruit which was deformed by Exoascus confusus Atkinson, earlier in the season. In each raceme are healthy fruits. From near Aetna, N. Y.

Plate VIII. Fig. 17, Exoascus decipiens Atkinson, blackening the leaves and shoot of Prunus americana Marshall. From Aetna, N. Y.

Fig. 18, Exoascus sp. deforming the shoot and leaves of Prunus virginiana L. From near Crowbar Point, west shore Cayuga Lake, N. Y.

Plate IX. Exoascus communis Sadebeck. Deforming the fruits of Prunus pumila L. From Horticultural grounds, Cornell University.

Plate X. Figs. 20–22. Exoascus deformans (Berk.) Fuckel. *a.* ascus, *st.* stalk cell, *hy.* cells of the hymenium, *ep.* epidermis, *m.* mycelium. Fig. 20 from LaFayette, N. Y., fig. 21, from Temple, N. H. Some of these asci have but four spores. Fig. 22 from Ames, Iowa.

Figs. 23, 24, Exoascus insititiæ Sadebeck, on leaves of Prunus pennsylvanica L., from Temple, N. H.

Fig. 25, Exoascus cerasi (Fuckel.) Sadebeck, from leaves of Prunus avium L., Germantown, Penn.

Plate XI. Figs. 26–32, Exoascus varius Atkinson on leaves of Prunus serotina L. Figs. 26–29 from Auburn, Ala., 30–31 from Smyrna, Del., 32 from Temple, N. H. Fig. 33 E. varius? from leaves of Prunus demissa Walp., Ute Pass, Colorado.

Plate XII. Figs. 34–36, Exoascus farlowii Sadebeck, on fruits of Prunus serotina L. Figs. 34–36 from Auburn, Ala., 35 from London, Canada.

Figs. 37–39, Exoascus confusus Atkinson, on fruits of Prunus virginiana L. 37 from Forest Home, N. Y., 38, 39, from Taburg, N. Y.

Plate XIII. Figs. 40–43, Exoascus communis Sadebeck? or E. mirabilis var. tortilis Atkinson? From deformed fruits of Prunus americana, cultivated varieties; 40, 41, 43, Cheny variety, 42, Baldwin variety. From Iowa.

Figs. 44, 45, Exoascus pruni Fuckel on fruit of Prunus domestica L., from Wisconsin.

Plate XIV. Exoascus longipes Atkinson, on fruit of Prunus americana Marshall. Fig. 46, section showing young hymenium etc., *c.*, cuticle, *h.*, hymenium, *ep.*, epidermis, *m.*, mycelium. 47, older hymenium showing the lower ends of the cells making their way in between the cells of the epidermis. 48, 50, 51, mature asci showing the stalk cells penetrating between the cells of the epidermis. 49, showing the successive development of the later hymenium and ascogenous cells. 52, a portion of the fruit where the subcuticular mycelium was not well distributed. From Danby, N. Y.

Plate XV. Exoascus rhizipes Atkinson, on fruit and bud of Prunus triflora Roxburgh. 53 and 55 from bud, 54, 56, 57, from fruit. Fig. 54 shows the young hymenium with the lower ends of the cells growing down between the cells of the epidermis. In the mature asci specimens are seen the rhizoids growing from the stalk cells. 57 represents some of these growing from the lower part of the ascus. Older fruit bodies have a much greater number of rhizoids. From Auburn, Ala.

Plate XVI. Exoascus communis Sadebeck. Figs. 58 and 59 from fruit of Prunus maritima Wang., Dartmouth, Mass. 60, from fruit of Prunus nigra Aiton, Alma, Mich.

Plate XVII. Figs. 61, 62, 63, 66, 67, Exoascus mirabilis Atkinson. 61 and 62 (type) from bud of Prunus angustifolia Marshall, Auburn, Ala., 63 from same in Iowa, 66 and 67 from buds of Prunus americana, Iowa.

Figs. 64 and 65, Exoascus mirabilis var. tortilis Atkinson, on fruit of Prunus angustifolia Marshall, from Auburn, Ala.

Plate XVIII. 70 and 72, Exoascus mirabilis Atkinson on buds of Prunus hortulana, L. H. Bailey, from Iowa, 71 same on P.

hortulana var. mineri., from Iowa. Fig. 68, highly developed specimens on bud of P. hortulana, Iowa. Fig. 69 from bud of Prunus domestica, N. J.

Fig. 73, Exoascus cecidomophilus Atkinson, on fruits of Prunus virginiana L. deformed by cecidomid larvæ. From Aetna, and other places in the vicinity of Ithaca, N. Y.

Plate XIX. Figs. 74–77, Exoascus decipiens Atkinson, on leaves of Prunus americana Marshall, from Danby, N. Y.

Figs. 78 and 79 Exoascus cecidomophilus Atkinson from fruits of Prunus virginiana L. deformed by cecidomid larvæ. In the vicinity of Ithaca, N. Y.

Plate XX. 81, 82 and 83 Exoascus mirabilis Atkinson from Prunus angustifolia Marshall, Auburn, Ala. 81 young hymenium and intercellular mycelium, 82 mature asci showing the connection of a portion of the hymenium with the mycelium, 83 superficial view of a portion of the hymenium. These figures are drawn to a different scale from 84 and 80 and this entire Plate is reduced more than Plates X–XIX.

Fig. 80 is from a petiole of a deformed bud and 84 from a deformed shoot of Prunus virginiana L. on which the fungus was not mature. In 80 is shown the intercellular mycelium and the very beginning of the hymenium underneath the cuticle. In 84 is shown a portion of the intercellular mycelium, after treatment with chloral hydrate.

PLATE I.—*Prunus persica* (*L.*), *Peach.* (*Exoascus deformans* (*B.*) *Fuckel.*)

PLATE II.—*Fig. 3.—Prunus americana Marshall, wild red plum (Exoascus longipes Atkinson). Fig. 4, Prunus triflora Roxburgh, Japan plum (Exoascus rhizipes Atkinson).*

PLATE III.—*Prunus americana Marshall, wild red plum* (*fig. 5 Exoascus longipes Atkinson, in ovaries; E. decipiens Atkinson in leaves, fig. 6, E. decipiens Atkinson in shoot. Fig. 7, E. decipiens Atkinson var. superficialis Atkinson, in surface of half grown plums*).

PLATE IV.—*Prunus angustifolia Marshall, Chickasaw plum (Exoascus mirabilis Atkinson var. tortilis Atkinson in plums).*

PLATE V.—*Prunus angustifolia Marshall, Chickasaw plum* (*figs. 10 and 11, Exoascus mirabilis Atkinson in buds; fig. 12, Exoascus mirabilis var. tortilis Atkinson in plums*).

PLATE VI.—*Prunus serotina L., wild black cherry* (*Exoascus farlowii Sadebeck in carpels, Exoascus varius Atkinson in leaves and shoots*).

PLATE VII.—*Prunus virginiana L., choke cherry (Exoascus cecidomophilus Atkinson in fruits deformed by cecidomid larvæ.*

PLATE VIII.—*Fig. 17, Prunus americana Marshall, wild red plum (Exoascus decipiens Atkinson blackening the leaves and shoot). Fig. 18, Prunus virginiana L., choke cherry (Exoascus sp. deforming the leaves and shoot.)*

PLATE IX.—*Prunus pumila L., dwarf cherry (Exoascus communis Sadebeck).*

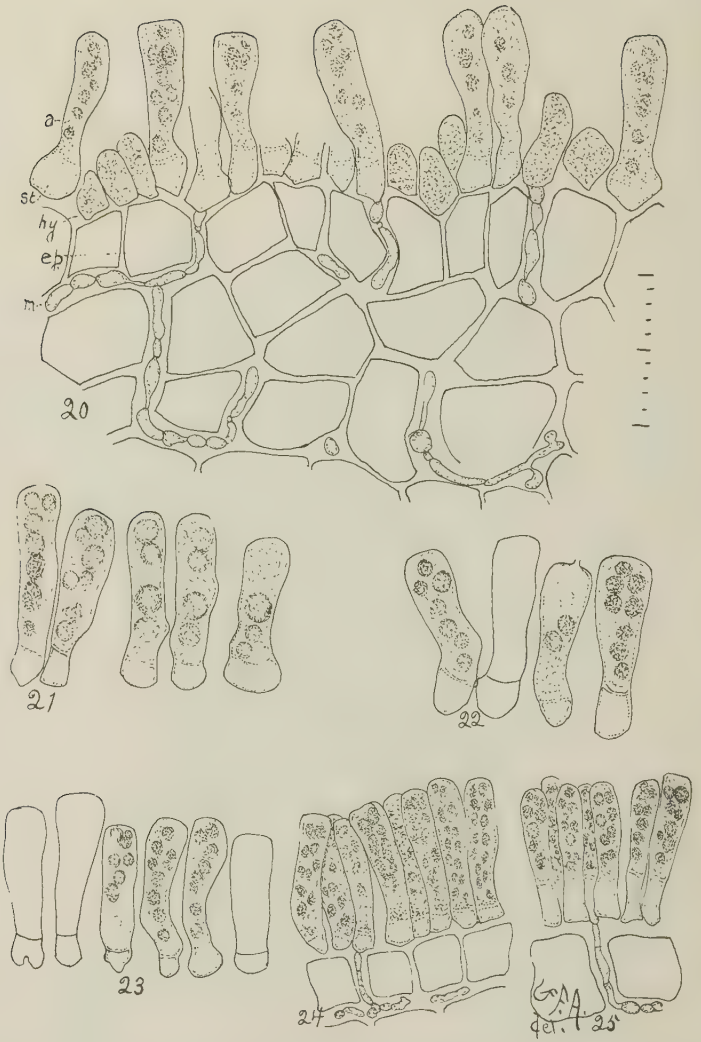


PLATE X.—*Figs. 20-22, Exoascus deformans (Berk.) Fuckel, (on P. persica L.). Figs. 23, 24, Exoascus insititiæ Sadebeck (on P. pennsylvanica L.). Fig. 25, Exoascus cerasi (Fuckel) Sadebeck, (on P. avium L.).*

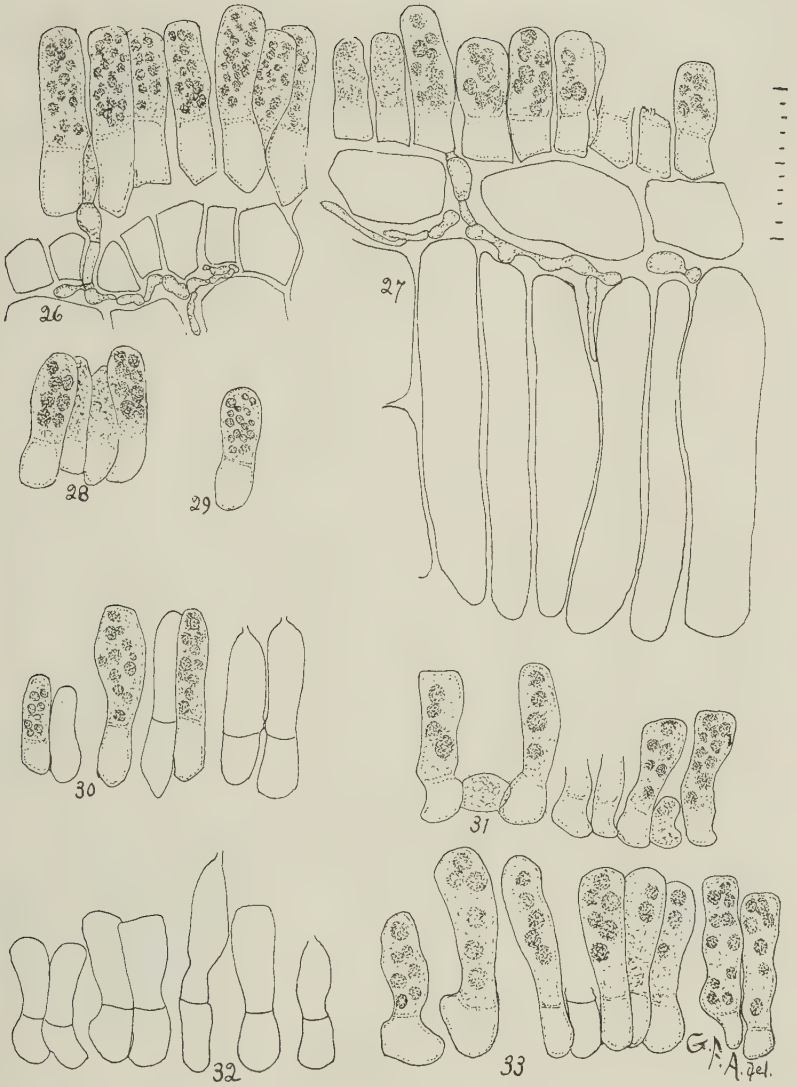


PLATE XI.—*Figs. 26-32, Exoascus varius Atkinson (on P. serotina L.). Fig. 33, E. varius? (On P. demissa Walp.).*

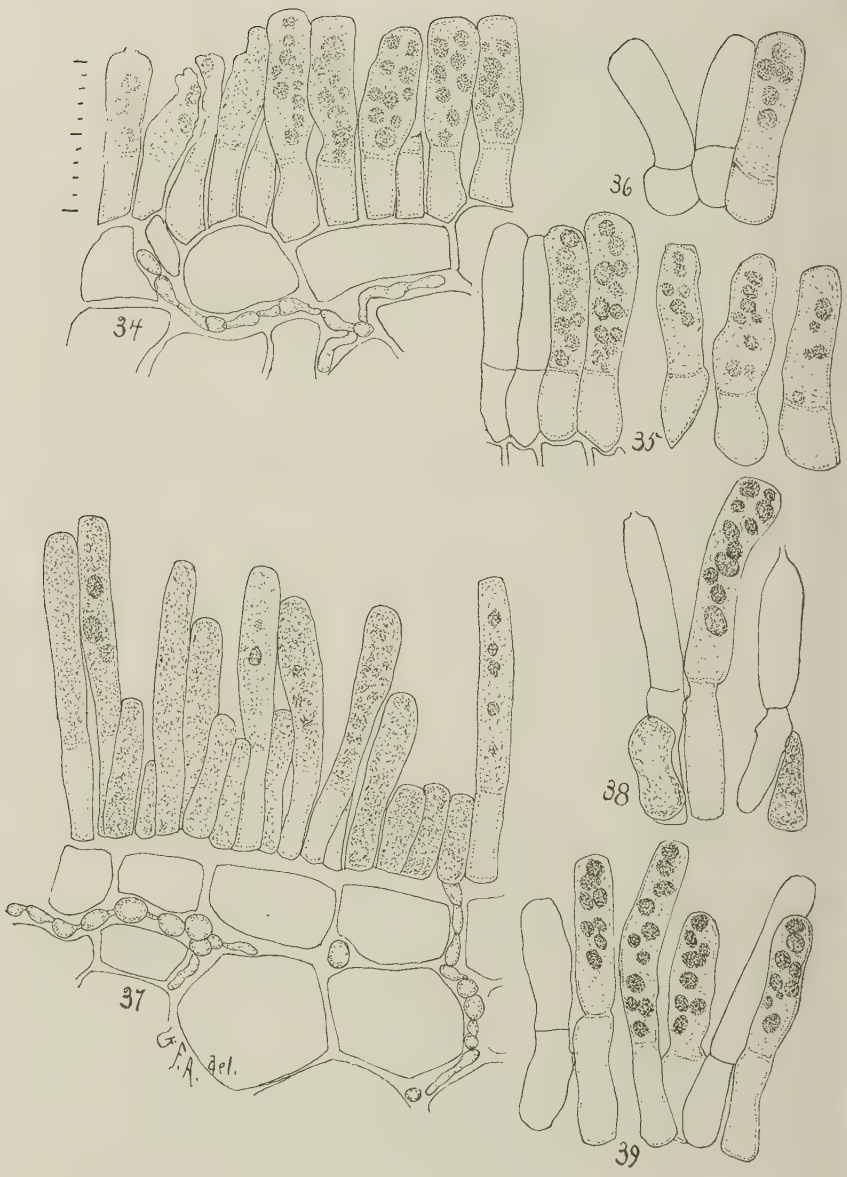


PLATE XII.—*Figs. 34-36, Exoascus farlowii Sadebeck (on P. serotina L.). Figs. 37-39, Exoascus confusus Atkinson (on P. virginiana L.)*

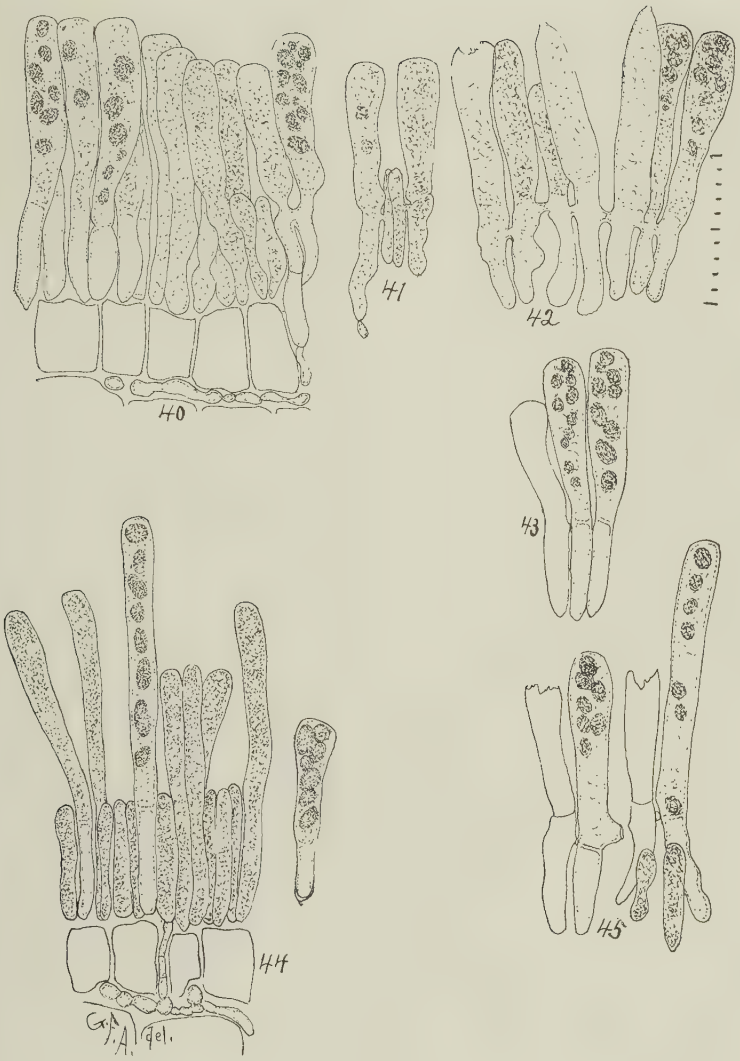


PLATE XIII.—*Figs. 40-43, Exoascus communis Sadebeck? or E. mirabilis Atkinson var. tortilis Atkinson? (on deformed fruit, P. americana Marshall). Figs. 44, 45, Exoascus pruni Fuckel (on P. domestica L.).*

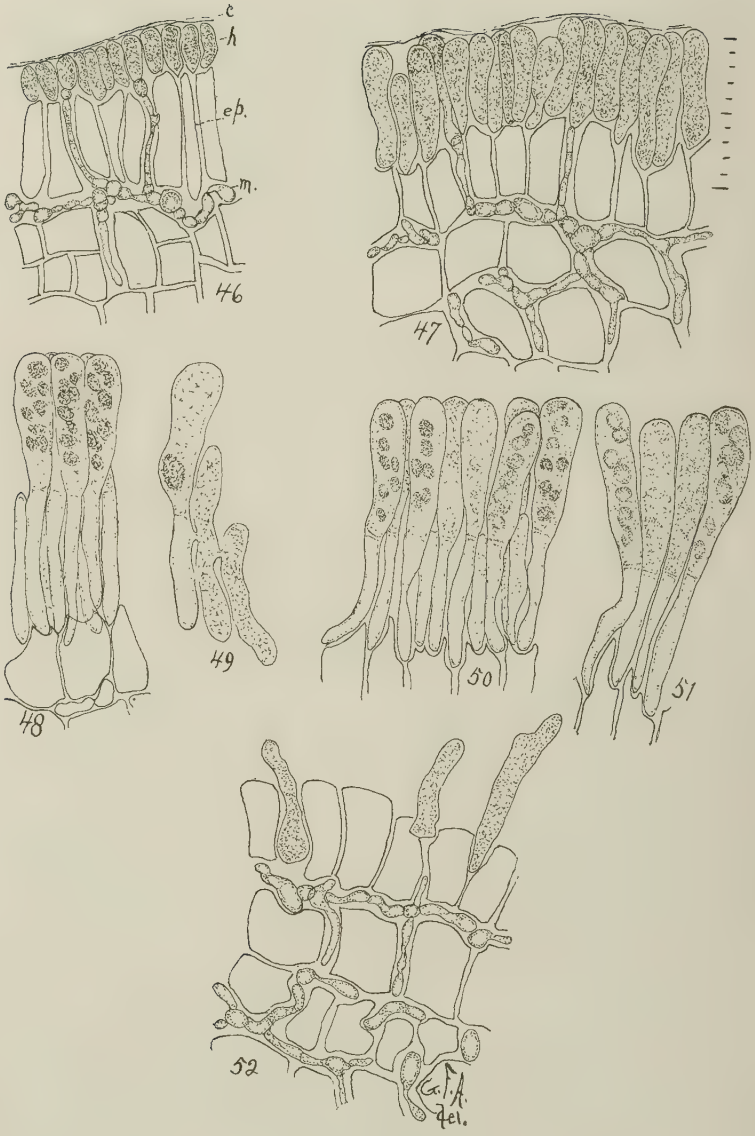


PLATE XIV.—*Exoascus longipes Atkinson* (*on P. americana Marshall*).

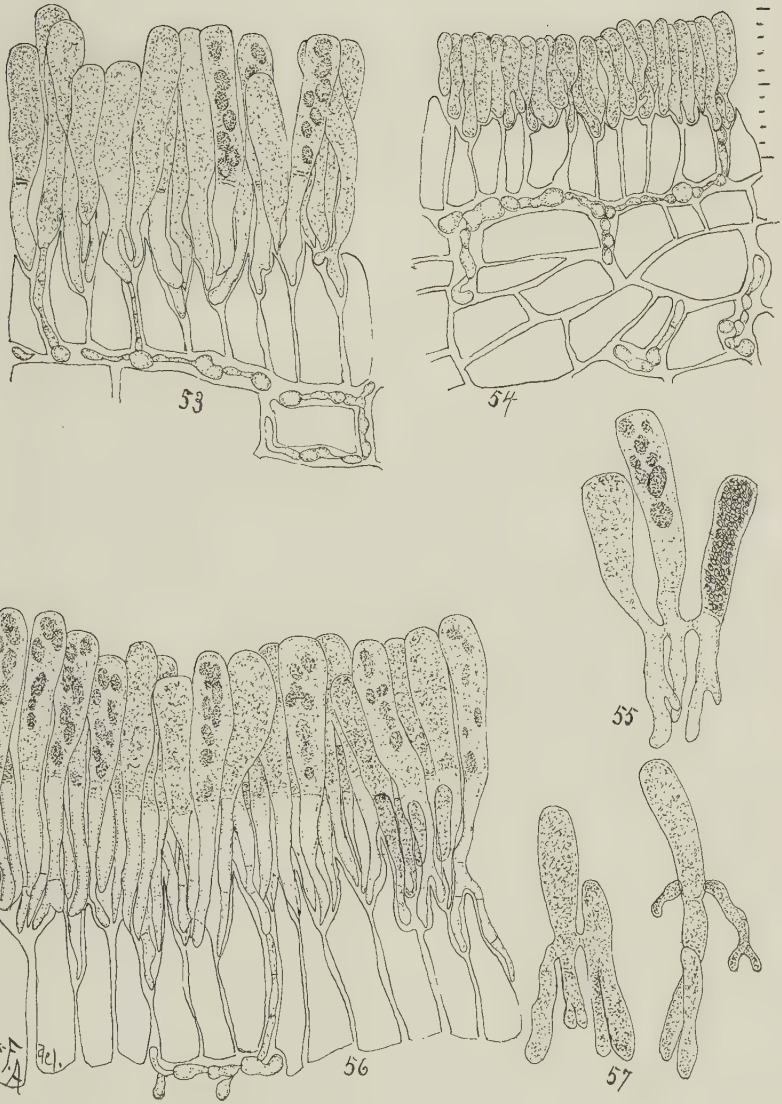


PLATE XV.—*Exoascus rhizipes Atkinson* (*on P. triflora Roxburgh*).

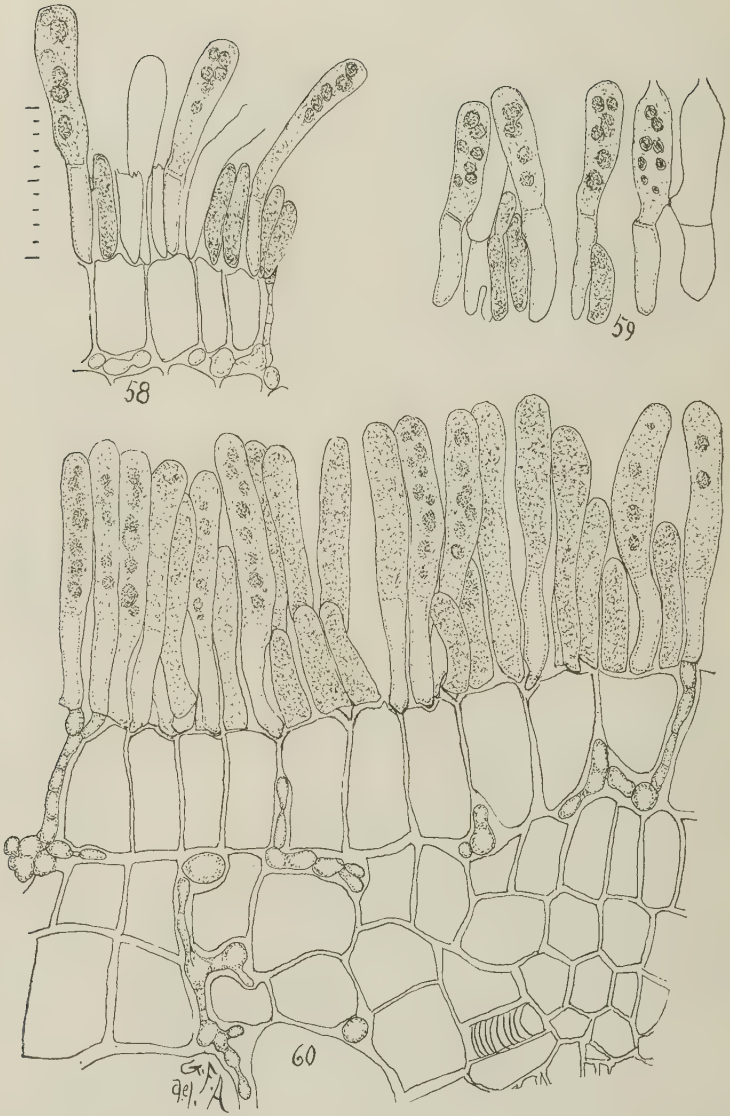


PLATE XVI.—*Exoascus communis Sadebeck* (*58, 59 on P. maritima Wang., 60 on P. nigra Aiton*).

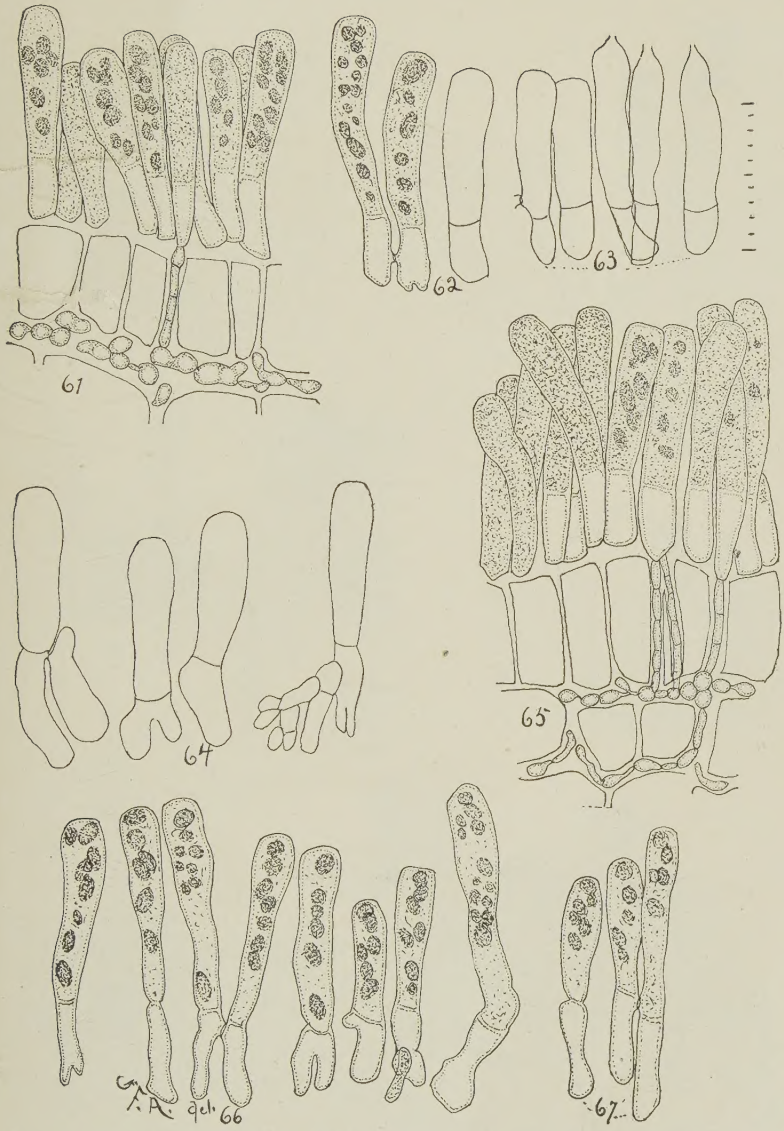


PLATE XVII.—*Figs. 61, 62, 63, Exoascus mirabilis Atkinson (on P. angustifolia Marshall); 66, 67, E. mirabilis Atkinson (on P. americana Marshall); 64, 65, E. mirabilis var. tortilis Atkinson (on P. angustifolia Marshall).*

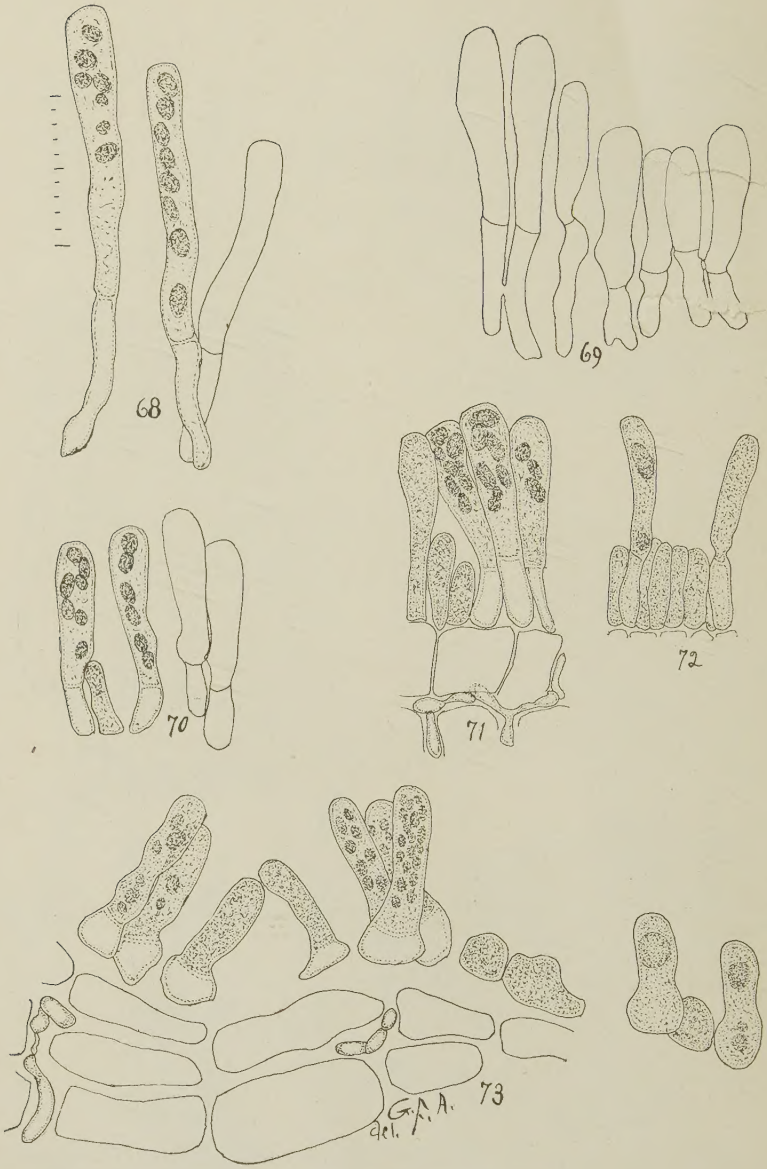
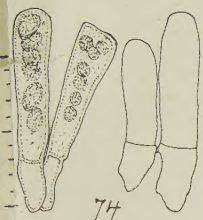
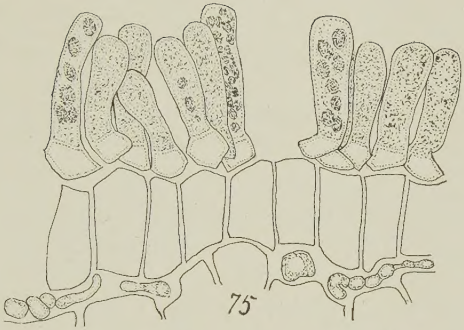
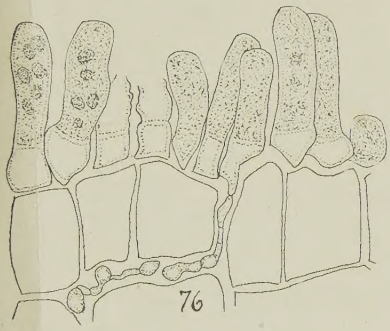


PLATE XVIII.—*Figs 68, 70, 71, 72, Exoascus mirabilis Atkinson (on P. hortulana L. H. Bailey, 71 on var. mineri). 69, Exoascus sp. (on shoot of P. domestica L.). Fig. 73, Exoascus cecidomophilus Atkinson (on P. virginiana L.).*







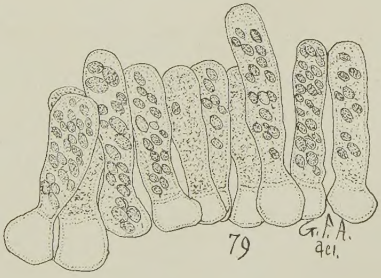
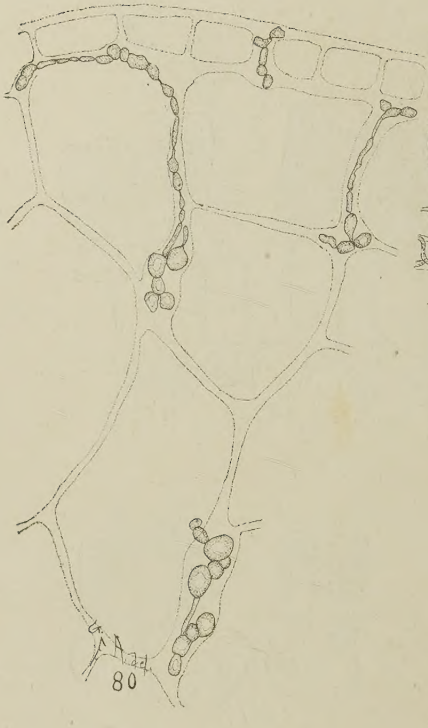
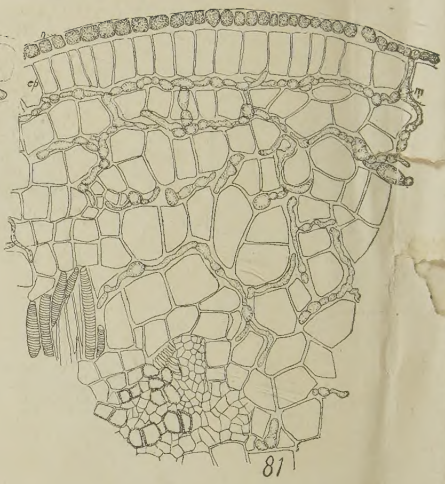


PLATE XIX.—*Figs. 74-77, Exoascus decipiens Atkinson (on P. americana Marshall); 78, 79, E. cecidomophilus Atkinson (on P. virginiana L.).*





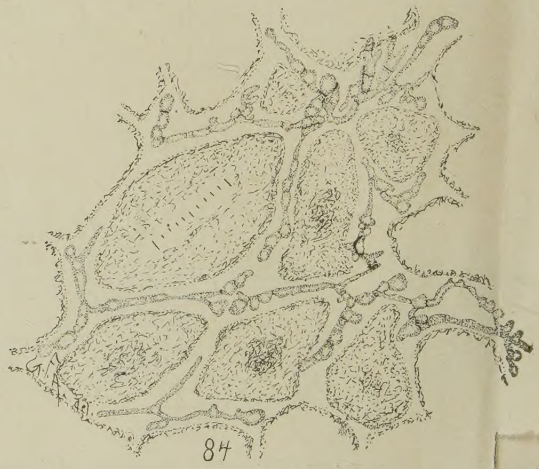


PLATE XX.—*Figs. 81, 82, 83. Exoascus mirabilis Atkinson (on P. angustifolia Marshall); 80, 84, Exoascus sp. (on P. virginiana L.).*